SIDON'S ANCIENT HARBOURS

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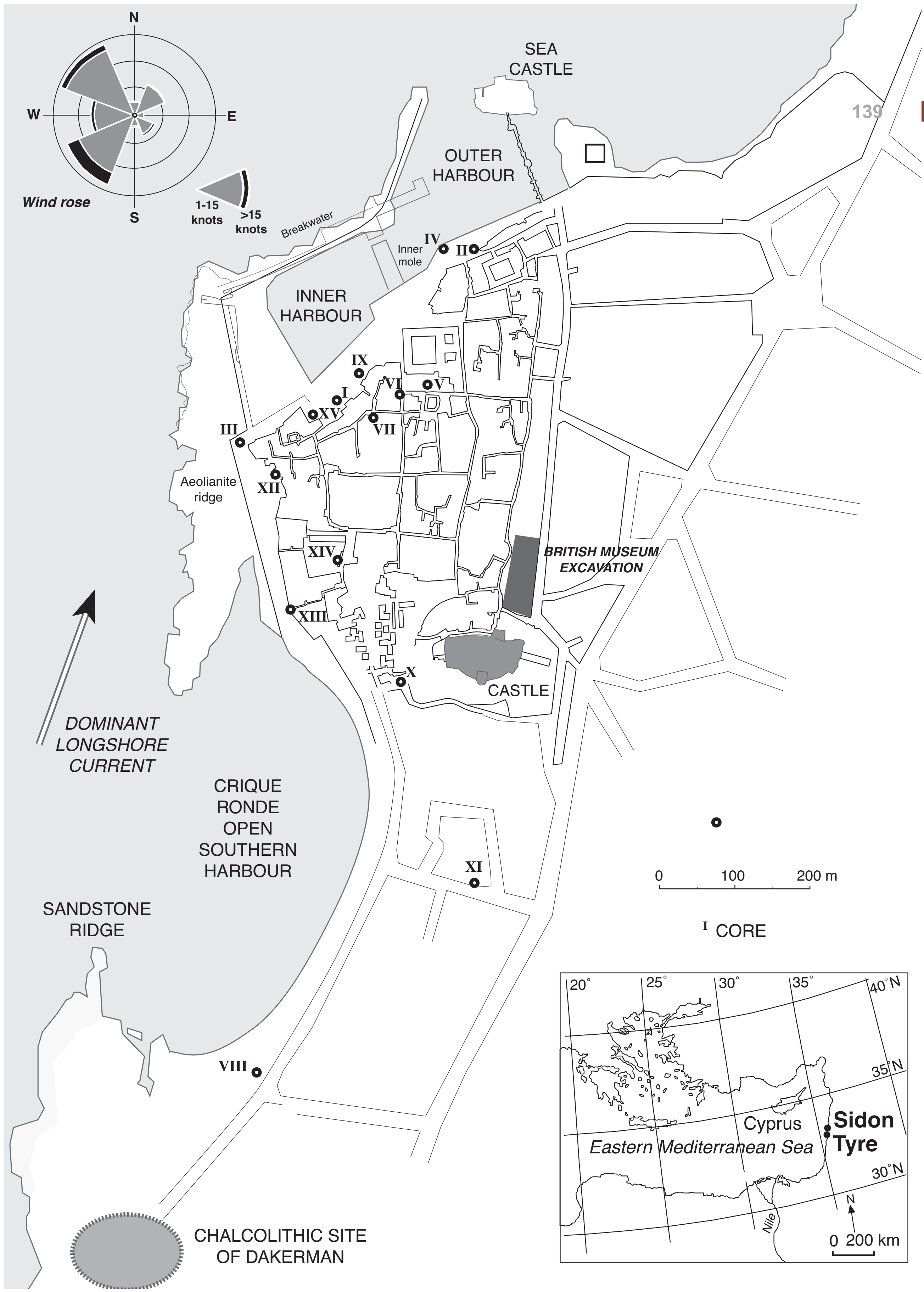
Abstract Excavations led by the British Museum have been underway at Sidon since 1998. In tandem with these archaeological surveys, 15 cores have been drilled in and around Sidon's ancient port areas, with three main objectives:
(1) to elucidate the evolution of the city's maritime façade and investigate its coastal palaeogeography;
(2) to compare and contrast these data with Sidon's sister harbours, Beirut, Byblos and Tyre; and
(3) to investigate human coastal impacts, and more specifically the problem of accelerated coastal sedimentation. Our geoarchaeological datasets elucidate a complex history of coastal change and human occupation. Investigation of the coastal archives has detailed six phases in Sidon's maritime history, between the Bronze Age and Medieval periods.

Introduction

The great antiquity of the Sidon-Dakerman area is attested by archaeological material dating back to the Neolithic (Saidah, 1979 ; Doumet-Serhal, 2003) (fig. 1). During the Iron Age, Sidon evolved into one of Phoenicia's key city-states reaching its apogee between the sixth and fifth centuries BC, at which time it superseded Tyre as Phoenicia's principal naval hub. While archaeological discovery at Sidon has a long and productive history beginning in the nineteenth century, the ancient city had never been systematically explored. It was only in 1998 that a team of archaeologists under the auspices of the British Museum and the DGA began large-scale excavations of the ancient tell, elucidating a quasi-continuous stratigraphy from the Early Bronze Age onwards (Curtis, 2000; Doumet-Serhal, 2003).

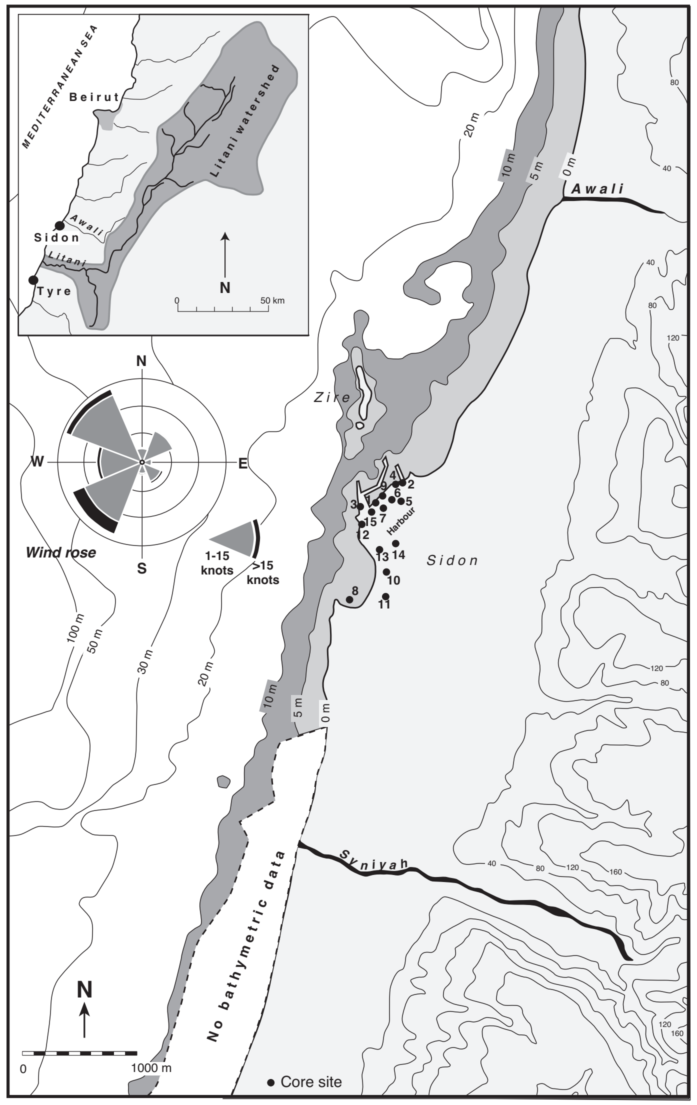
In tandem with the terrestrial excavations, 15 cores were drilled in and around Sidon's port areas, with three main objectives: (1) to expound the coastal palaeogeography (Espic *et al.*, 2002; Morhange *et al.*, 2003a; Marriner *et al.*, 2006); (2) to compare and contrast these data with Sidon's Phoenician sister harbours (Marriner and Morhange, 2006; Marriner *et al.*, 2006); and (3) to investigate the problem of accelerated coastal sedimentation. Silting up of the harbours played a significant role in the human exploitation of the ancient anchorages (Morhange *et al.*, 2003b; Raban 1985 and 1987a). Recent research has shown that ancient societies strived permanently with the silting problem, and indeed in areas of high sediment supply it was a constant endeavour to maintain a viable draught depth (Marriner and Morhange, 2006).



1. Sidon's ancient harbour areas and location of cores.

Geomorphological context

Sidon's coastal plain runs from the Litani river in the south, northwards towards the Awali river (fig. 2). This low-lying topography, up to 2 km wide in places, comprises a rectilinear coastline and a series of faults has oriented the talwegs NW-SE (Dubertret, 1955 and 1975; Sanlaville, 1977). The most important watercourse in the Sidon vicinity is the Awali, which transits ~130 x 10^6 m^3 of sediment per year.



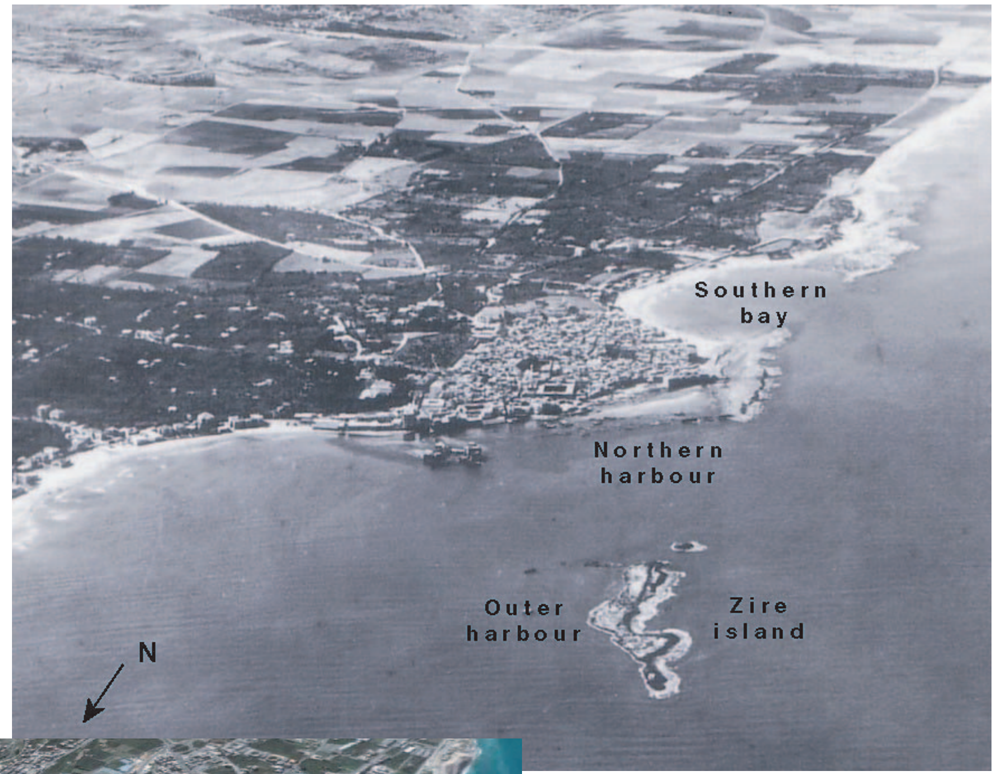
2. Sidon's coastal bathymetry.

Sidon's coastal physiography makes it an ideal location for the establishment of three natural anchorage havens. Two pocket beaches lie leeward of a Quaternary sandstone ridge, partially drowned by the Holocene marine transgression (Morhange *et al.*, 2006; fig. 3). To the south of the ancient city this ridge has been breached by the sea to form a small embayment named the *Crique Ronde* by Poidebard and Lauffray (1951). Whether or not it was ever artificially protected by harbourworks has never been unequivocally demonstrated, a question we elucidate later in this paper.

North-west of the promontory lies a second bay, protected from the open sea by a prominent sandstone ridge. 580 m in length, this coastal ridge shields a shallow basin still used to this day. This northern harbour was the centre of Sidon's activity in antiquity. Poidebard and Lauffray (1951) identified the vestiges of a closed ancient port comprising:
(1) a reinforced sandstone ridge; and
(2) an inner mole, perpendicular to the ridge, and separating two basins.

A third harbour area, the offshore island of Zire, is a unique feature of the Sidonian coastal façade (fig. 3). First described by Renan, it was not until Poidebard and Lauffray (1951) took charge that a preliminary plan of the island was drawn up. A double seawall shelters a series of quarries and harbour quays on its leeward side. Underwater surveys by Frost (1973) uncovered a collapsed jetty and numerous scattered masonary blocks on the sea bottom. She concluded that the island had not only served as a quarry and harbour but also supported a number of constructions. Carayon (2003) has recently undertaken new research on the island, and describes six quarry zones. We recently dated an uplifted marine notch (+50 cm) on these quarry faces, pertaining to a short-lived sea-level oscillation around 2200 years BP (Morhange *et al.*, 2006). These data are in contrast with Tyre, where submergence of ~3 m is recorded since late antiquity (El Amouri *et al.*, 2005; Marriner *et al.*, 2005).

3. Above: Sidon and Zire during the 1940s (from [31]). Below: Sidon and Zire in 2005. Note the extensive modernisation of the coastal front in both the northern harbour and southern bay. In the foreground, Sidon's outer harbour lies in the shadow zone of Zire island. The promontory of Sidon separates two coves, the northern harbour and Poidebard's *Crique Ronde*, Poidebard & Lauffray, 1951).



Detailed descriptions of the litho- and biostratigraphical datasets, in addition to the methods employed, are given in Marriner *et al.* (2006). Here, we briefly summarise the key findings from our recent research looking to better understand coastal dynamics and shoreline evolution in the northern harbour and southern cove.

Results

The northern harbour

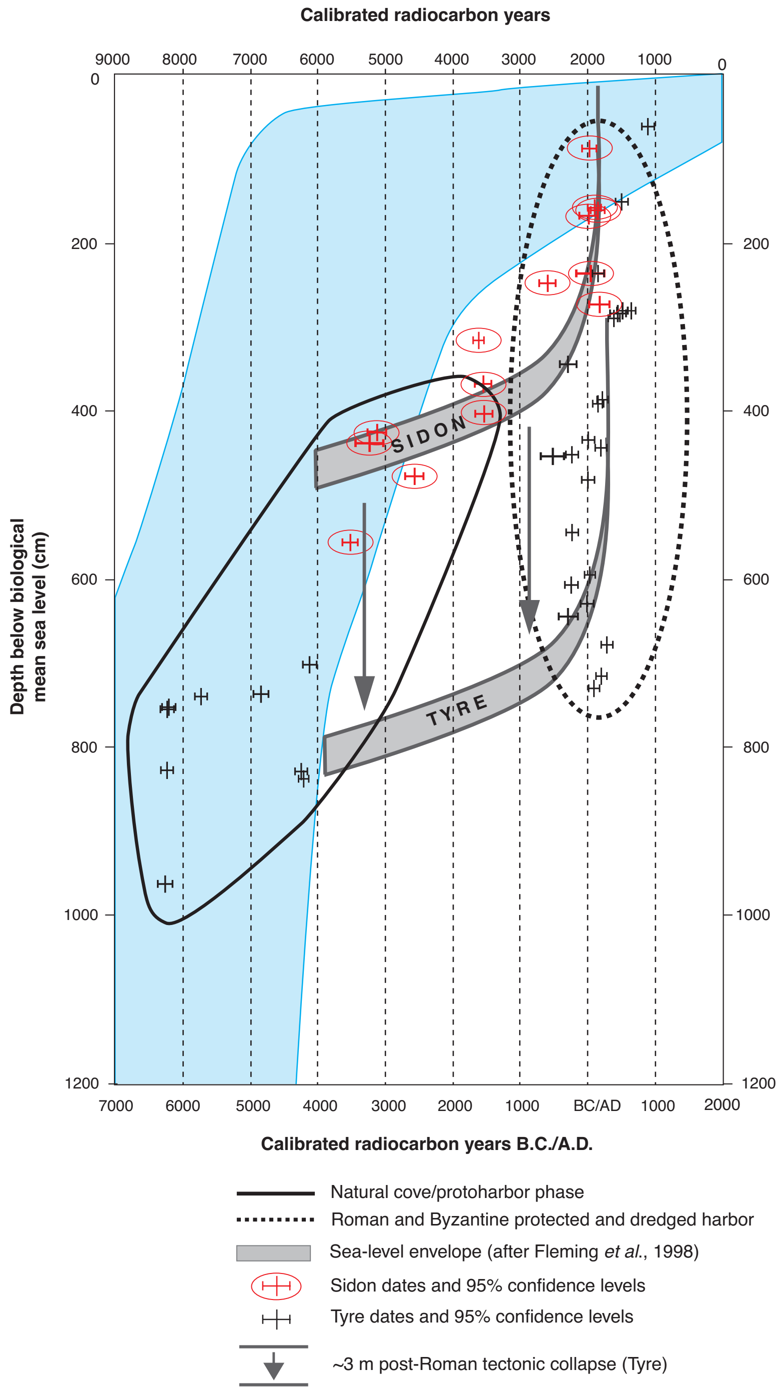
The coastal stratigraphy from the northern harbour is composed of five facies.

1 Pocket beach (*ca.* 3500-1500 cal. BC)

The marine flooding of the cove is dated ~6000 BP. A basal unit comprising subtidal sands is analogous to a medium/low energy pocket beach, sheltered by the sandstone ridge.

2 Artificial Bronze Age cove (*ca.* 1500-1000 cal. BC)

A fall in energy dynamics is translated by a rise in the silts fraction. This facies corresponds to the Middle to Late Bronze Age proto-harbour (Frost, 1995, Raban, 1995), with possible reinforcement of the sandstone ridge improving the quality of the anchorage. Small boats would have been hauled onto the beach face, with larger vessels being anchored in the embayment.



4. Chronostratigraphic evidence for Roman and Byzantine dredging of Sidon and Tyre's ancient harbours. The older radiocarbon group corresponds to a naturally aggrading marine bottom. Quasi-absence of chronostratigraphic record between BC 4000 to 500, coupled with persistent age depth inversions, are interpreted as evidence of harbour dredging.

3 Closed Phoenician to Roman harbours (ca. 1000 cal. BC-300 cal. AD)

Between the Phoenician to Roman periods, a net change is observed in sedimentary conditions with a marked shift to silts and fine sands, concomitant with a low energy environment. A rise in lagoonal molluscs and ostracods is in compliance with anthropogenic sheltering of the environment by harbourworks. Persistent age-depth anomalies provide strong chronostratigraphic evidence for dredging from the Roman period onwards (fig. 4).

4 Closed late Roman and early Byzantine harbours (ca. 300-600 cal. AD)

Accentuation of low energy conditions is manifested by a plastic clays unit. The silts and clays fraction comprises >90 % of the sediment. Radiocarbon ages are often stratigraphically incoherent for this facies. Lagoonal and muddy sand taxa support an extremely well protected, lagoon-like harbour.

5 Exposed Islamic harbour

A sharp rise in the gravels and coarse sands fractions appears concomitant with a gradual demise in harbour maintenance. Biostratigraphic data corroborate a reopening of the environment to the influence of offshore marine dynamics, with numerous taxa from the subtidal sands assemblage. This facies could correspond to the gradual demise of Sidon as a commercial centre during the Islamic period.

Southern cove

The southern cove is characterized by three lithostratigraphical units.

1 Holocene transgression (ca. 4500 cal BC)

The sandstone substratum is overlain by a pebbly sand unit marking the Holocene marine transgression of the cove. This subsequently grades into a coarse shelly sand unit typical of a shallow marine embayment.

2 Bronze Age pocket beach

The molluscan fauna is diverse, with tests from a range of ecological contexts including subtidal sands, the upper muddy-sand assemblage in sheltered areas, the upper clean-sand assemblage, the silty or muddy-sand assemblage and the lagoonal assemblage. Marine lagoonal ostracod taxa persist into this unit and are accompanied by a gradual rise in coastal taxa. Sporadic tests of marine species indicate continued communication with the open sea.

At no point during antiquity do our sedimentological and palaeoecological data show evidence for artificial harbourworks in the southern cove. During the Bronze Age this embayment would have served as a fair weather harbour for the inhabitants of Sidon and Dakerman. The wide sandy beaches prevalent in the southern cove would have accommodated smaller vessels, drawn from the water onto the beachface. This phenomenon is still practiced today throughout the Mediterranean by fishermen with light, shallow draught vessels. Larger vessels would have sought shelter in the better protected northern harbour.

3 Prograding shoreline

The final unit comprises shelly sands with an important rise in the gravels fraction concomitant with a prograding shoreline. The molluscan fauna comprises badly preserved tests and shell debris, reworked by wave action.

Under a context of stable relative sea level and moderate to high sediment supply, Sidon's southern cove gradually prograded seawards, dimishing the cove to its present disposition. The absence of artificial harbourworks and relative persistence of middle energy coastal dynamics means that this littoral deformation is less pronounced than the northern harbour.

Discussion

Our geoarchaeological datasets elucidate a complex history of coastal change and human occupation. Harbour management advances are clearly translated by distinctive sedimentary facies and faunal suites. The sedimentary history of the northern harbour details six periods.

1 Bronze Age proto-harbour phase

At the time of Sidon's foundation, during the third millennium BC, maritime harbour technology was still very much in its infancy (Wachsmann, 1998; Marcus, 2002 ; Fabre, 2004-2005). Existing Bronze Age evidence from the Levant shows a clear pattern of environmental determinism, whereby populations founded settlements in proximity to naturally occurring anchorages such as leaky lagoons, estuaries and protected pocket beaches (Raban, 1987b, 1990). At Bronze Age Sidon, the northern and southern pocket beaches were ideally predisposed to serve as proto-harbours. The northern cove afforded the best natural shelter for larger merchant boats during storms. Conversely, the sandy beaches prevalent in the

southern cove would have accommodated smaller vessels, drawn from the water onto the beachface.

2 Dating the beginnings of the artificial harbour

Towards the end of the Late Bronze Age and the Early Iron Age (~1200-1000 BC), expanding international trade prompted coastal populations into modifying these natural anchorages. For example, the Phoenician mole at Atlit has been dated to the ninth century BC (Haggai, 2006). Another archetype derives from Tabbat el-Hammam in Syria, where a quasi-identical mole has been dated to *ca.* the ninth/eighth centuries BC (Braidwood, 1940). More speculative examples of harbour infrastructure are known from the Levantine coast (Frost, 1995). In Sidon's northern harbour, transition from shelly to fine-grained sands appears to be the first granulometric manifestation of human coastal modification. A single radiocarbon date constrains this alteration to the Middle Bronze Age (~1700 cal. BC) and must be confirmed by further data. The bio-sedimentological datasets show that it was the northern harbour, naturally protected from the open sea by a sandstone ridge, which became the city's major port basin. Conversely, there is no sedimentary evidence for harbourworks in the southern cove.

Difficulty in dating this first phase of artificial confinement appears concurrent with two complimentary dynamics (1) modest artificial harbourworks during the Middle and Late Bronze Age or (2) intense dredging during the Roman and Byzantine occupations.

3 Absence of Iron Age sedimentary archives

Given the relative absence of pre-Hellenistic facies, reconstruction of the northern harbour's phoenician history is problematic. In effect, advanced harbour management techniques during the Roman and Byzantine periods culminated in the repeated dredging of the northern harbour, removing this strata from the sedimentary record (fig. 4).

Siltation, notably under deltaic and urban contexts, was a well-recognized problem in antiquity with four sedimentary sources of note: (1) local watercourses; (2) regional longdrift currents; (3) erosion of adobe constructions and urban runoff; and (4) use of the basin as a base-level waste dump. Sidon's gravels fraction from the Roman period comprises a whole suite of discarded objects, trapped at the bottom of the basin, including ceramics, wood, seeds, leather artefacts etc.

4 The Roman revolution

By Roman times, the discovery and use of hydraulic concrete greatly enhanced engineering possibilities, locally deforming coastal landscapes (Brandon, 1996; Oleson *et al.*, 2004). In effect, at this time we observe pronounced transition from environmental to anthropogenic determinism. The Romans were able to conceive long breakwaters or offshore harbour basins, Caesarea Maritima being an example *par excellence* (Blackman, 1996). All-weather basins could be constructed at locations where no natural roadstead existed. During this technological revolution, Sidon's northern harbour underwent significant changes with the edifice of an inner artificial mole perpendicular to the sandstone ridge. This yielded an extremely well-protected inner basin, translated in the geological archive by a silt facies containing lagoonal molluscs and microfossils.

Under these closed conditions sedimentation rates rose significantly (~1 mm/yr during the mid-Holocene compared to ~10 mm/yr for the Roman period), not least because of the overriding confinement, but also linked to increasing human use and abuse of the surrounding watershed that flushed sediment into harbour depocentres.

In addition to artificial dredging, engineering solutions to the siltation problem have been asserted, although many of these remain speculative (Blackman, 1982 a and b). In Sidon, Poidebard and Lauffray (1951) identified a flushing channel, linking the northern basin with the open sea. The stratigraphy shows dredging and coeval desilting infrastructure to have been insufficient in eradicating the problem; two thousand years later, rapid silting up means that the majority of the ancient basin is now buried beneath the Modern city centre.

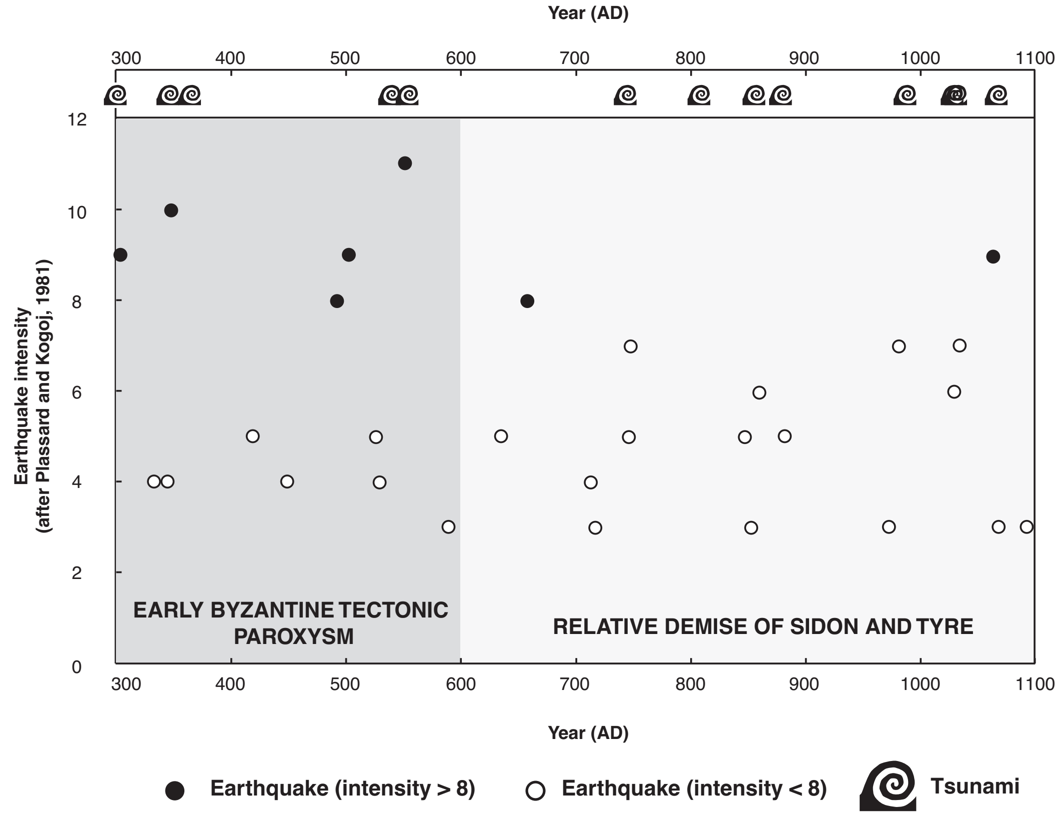
5 Byzantine apogee

While Bronze Age populations benefited from Sidon's geological endowment, Byzantine societies inherited the Romans' rich maritime *savoir faire*. The Byzantine period is marked by advanced reinforcement of the antecedent port infrastructure, with a notable persistence of Roman technology and its opulent legacy of engineering achievements (Hohlfelder, 1997). This is corroborated by a plastic clay unit with diagnostic lagoonal fossils, typical of pronounced confinement. These geological data support archaeological evidence from Beirut's Byzantine harbour suggesting that the Levantine coast was still an important trade zone at this time (Saghieh Beydoun, 2005). Such a trade apex, coeval with advanced port infrastructure and management techniques, leads us to propose a harbour apogee for Sidon during the Byzantine period.

6 Harbour abandonment phase

Radical coastal changes are witnessed during the Islamic period, with a gradual reopening of Sidon's northern harbour. We advance three hypotheses to explain these data, namely (i) cultural, (ii) tectonic and (iii) tsunamogenic:

(i) Historians traditionally argue that the Byzantine crisis (sixth century AD) and ensuing Islamic conquest (seventh century AD) engendered profound changes in the eastern Mediterranean's trade network (Pirenne, 1937). It was speculated that harbour infrastructure fell into a state of disrepair. *A priori* our sedimentological data are consistent with these interpretations. Nevertheless, recent archaeological and historical research tends to moderate the premise of a general decline of 'Syrian' harbours (Borrut, 1999-2000). Historians believe the Levantine coast to have been the cradle of Islamic maritime development, control which opened the gates of the Mediterranean (Borrut, 2001). Our data indicate rapid coastal



5. AD 300 to 1000 earthquake and tsunami events affecting the Phoenician coast (data compiled from Ambraseys, 1962; Plassard and Kogoj, 1981; Russel, 1985; Guoidoboni *et al.*, 1994; Soloviev *et al.*, 2000).

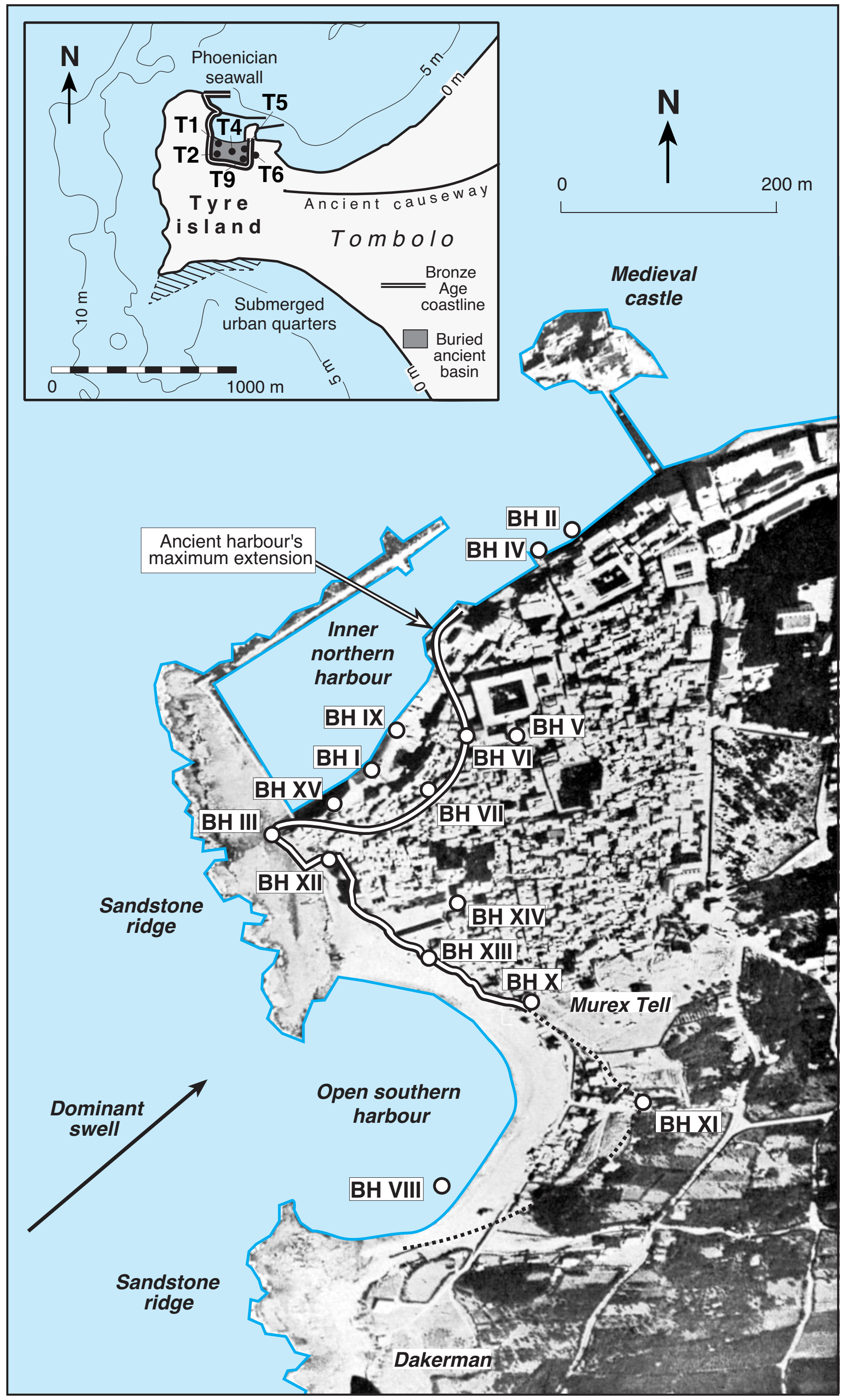
progradation from the sixth century AD onwards, entraining the dislocation of Sidon's harbour. Although smaller, it is difficult to accurately constrain the exact dimensions of this port as the post-Byzantine sediment record lies beneath the present basin and is not accessible at present.

(ii) Data of the opening of Sidon's harbour chronologically contradict the Early Byzantine Tectonic Paroxysm dated to the fourth to sixth centuries AD (Pirazzoli, 1986, Pirazzoli *et al.*, 1996). In effect, this opening appears to be later, after the sixth century AD. Fig. 5 plots earthquake and tsunami events on the Levantine coast illustrating that the fourth to eleventh centuries were characterised by repeated seismic shocks, possibly provoking partial harbour damage.

(iii) This discrepancy leads us to moderate tectonic mobility in favour of tsunamogenic impacts. In effect, more than ten tsunami struck the Levantine coast between the fourth to eleventh centuries AD, severely damaging harbour infrastructure. Notwithstanding these catastrophist scenarios, Sidon port is still in use today, 5000 years after its foundation.

Conclusion

Although Sidon had three port complexes during antiquity, the northern basin, sheltered by an extensive aeolianite ridge, was naturally predisposed to become the main seaport from the Bronze Age onwards. As with many of the ancient seaports on the Levantine façade, Sidon's northern harbour is an example of a buried urban harbour *par excellence*. Diagnostic harbour facies have been elucidated around the fringes of the present fishing harbour, for a distance of 100 m inland (fig. 6). Coastal progradation of the port coastline after the Byzantine period, diminished the size of harbour to its present dimensions. As at Tyre, this land encroachment accommodated urban growth during the medieval and modern periods.



6. Sidon's reconstructed harbour limits in antiquity.

In conclusion, we would like to insist on three research advances:

(1) It has been demonstrated that harbour history can be clearly chronicled by diagnostic litho- and biostratigraphies. Indeed, explicit use of the coastal sedimentary record has the possibility to greatly enhance our understanding of human-environment interactions; we therefore postulate geoscience to be a powerful tool in expounding the spatial organisation of harbour areas and their coastal evolution through time.

(2) For Sidon, a clear transition is manifest in the stratigraphy from environmental determinism during the Bronze Age, through various intermediary phases, to full anthropogenic determinism by the Roman period.

(3) Emerging geological data delineates a largely analogous chronostratigraphic pattern for many of the Mediterranean's ancient ports. The most important factors in explaining coastal progradation are not small scale relative sea-level variations but anthropogenic sediment supply and harbour management.

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